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by

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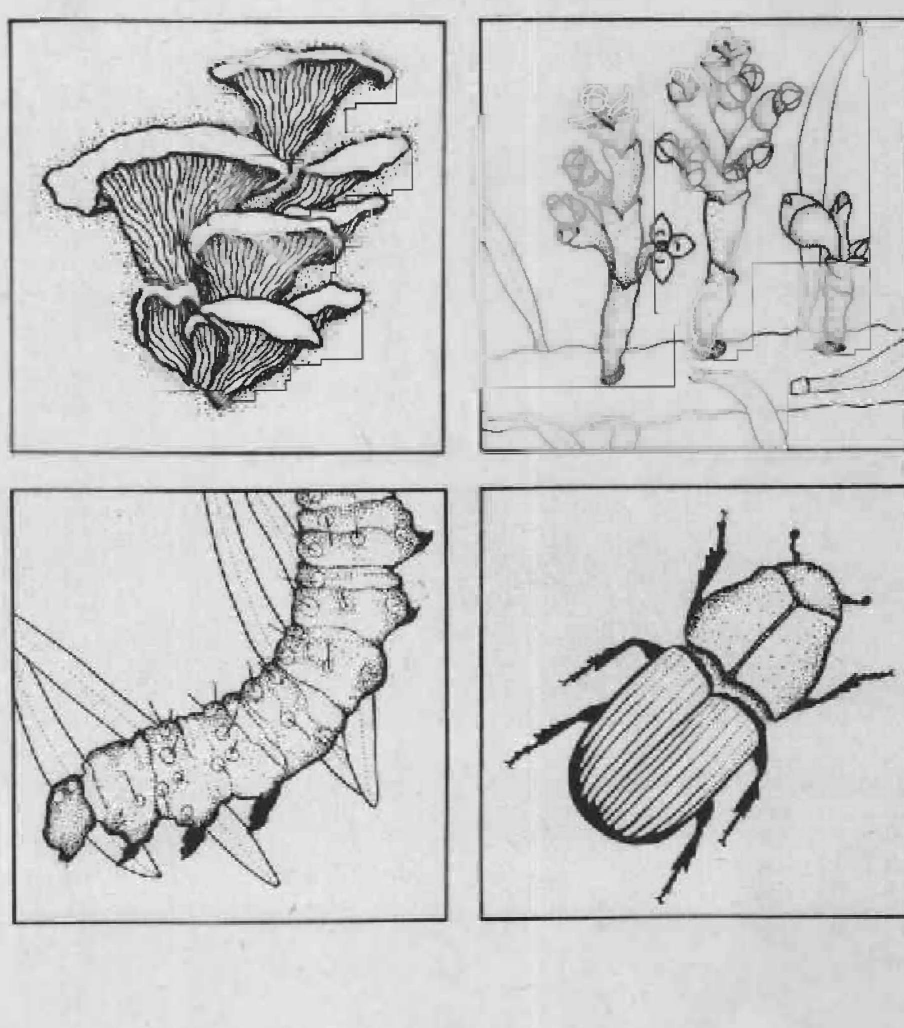

DETERMINATION OF WESTERN PINE SHOOT BORER INCIDENCE, IMPACT, AND STAND HAZARD RATING CHARACTERISTICS IN SELECTED REGION ONE NATIONAL FORESTS

by

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INTRODUCTION

Increasing attention and investment are being directed towards intensive fiber and timber oriented forest management systems. Due to the increased costs associated with intensive management, any factors which significantly reduce projected value yields need to be identified and their effects evaluated. Ponderosa pine, *Pinus ponderosa* Laws., is a preferred host of the western pine shoot borer, *Eucosma sonomana* Kft., (Lepidoptera: Olethreutidae). This insect has been identified as causing substantial reduction in height growth and form of ponderosa pine in plantations established in eastern Oregon (Stoszek 1973), Colorado, Arizona, New Mexico (Stevens and Jennings 1977), northern Idaho (Luther 1980), and central Idaho (Stoszek et al. 1981). Stoszek (1973) estimated that volume losses attributable to the shoot borer in eastern Oregon amounted to as much as 25 percent of the undamaged harvest volume. In central Idaho cumulative volume losses in 80 year old plantations of certain site and stand conditions were estimated to be as high as 13 percent (Stoszek et al. 1981). Aside from volume losses there is also a substantial value loss associated with reduction of form classes due to forking.

Control measures for the shoot borer have been developed (Sower et al. 1979, Sartwell et al. 1980b, Overhulser et al. 1980). Thus, the need to identify plantations which are subject to high levels of shoot borer infestation and consequently high volume losses becomes apparent. Once "high risk" areas are identified managers will be able to weigh the costs of controls against the costs associated with shoot borer losses.

OBJECTIVES

The objectives of this survey were:

1. To assess the incidence of shoot borer infestation in young ponderosa pine plantations in western Montana and northern Idaho.

2. To appraise the relationships between the incidence of shoot borer and the attributes of the plantation and develop a western pine shoot borer hazard rating system.

3. To assess the impact of shoot borer infestation on height growth of ponderosa pine plantations.

METHODS

Biology.--The western pine shoot borer, a native American moth, is found throughout the range of its principal host, ponderosa pine (Sartwell et al. 1980a). The adult moths emerge in early spring and lay eggs on the buds of their host. Egg hatching and larval activity begins at the start of shoot elongation in the spring. The larva bores directly into the pith region and feeds downward as the bud elongates. By midsummer the larva emerges from the shoot, drops to the ground and pupates in the duff, overwintering in this stage.

External symptoms of shoot borer infestation persist for several years after larval emergence and therefore supply information about recent infestation rates. These symptoms include: shortening of the needles and decreased spacing between stem units on the infested portion of the shoot; an approximately one-eighth inch emergence hole; swelling of the shoot in the vicinity of the emergence hole in years subsequent to the year of infestation; and a reduction in the terminal/lateral shoot ratio (Stoszek 1973).

All ponderosa pine plantations in the 12- to 18-year age class in the western portion of Region 1 comprised the sample population. These plantations were stratified according to geographic region (northwestern Montana--Kootenai and Flathead National Forests; west-central Montana--Lolo and Bitterroot National Forests; and northern Idaho--Clearwater and Panhandle National Forests). The Nezperce National Forest has previously been sampled for shoot borer by Robertson (1982) and Stoszek et al. (1981). Further stratification of sample plantations was based on vegetation series, i.e., ponderosa pine, Douglas-fir, grand fir, and subalpine fir (Daubenmire & Daubenmire 1968, Pfister et al. 1977), and elevational zone (3,000-4,500 ft; 4,600-5,500 ft; and 5,600-7,000 ft). From a total population of 300 plantations, 80 were selected for sampling. The number of plantations sampled within each stratum was proportional to the total number of plantations in that stratum. Within each plantation sampled, data on shoot borer infestaion rate and tree characteristics were collected using replicated systematic samples with random starts. Each of 10 samples consisted of a transect of two points at a 2-chain interval. The first point was 1 chain from the plantation boundary. Each transect lay perpendicular to the longest plantation boundary and started at a randomly selected distance along the boundary. At each point on the transect the nearest ponderosa pine was sampled for the following information: total height, height growth increment by year for 1978 through 1981, shoot borer infestation status of the terminal by year for 1978 through 1981, year of loss of terminal dominance, and indications of other damage. One of the two points on each transect served as the center for a 1/100-acre circular plot in which all trees (host and nonhost) were measured for height, diameter at breast height, and crown ratio. In addition the following information was collected for each plantation: elevation, physiography, slope, aspect, soil characteristics, geologic parent material, habitat type, method of planting, and site preparation technique.

ANALYSIS

Individual tree data was summarized to produce average growth rates, stocking densities, stand characteristics and shoot borer infestation rates for each plantation. Infestation rates for all plantations within a single sample stratum were used to calculate an average infestation rate and confidence interval for that stratum.

Single variable regression models were developed (Nie 1975) to test the relationshps between individual site and stand characteristics and the incidence of shoot borer infested terminals. Stepwise regression was used to develop a multivariable hazard rating model for the prediction of shoot borer infestation rates in young ponderosa pine plantations.

All further data analysis was conducted on transformed infestation rate data. The transformation used was:

$$\text{Infestation rate in radians} = \text{Arcsine } \sqrt{\frac{\text{percent infestation}}{100}}$$

Any calculations using models in this report will yield infestation rates in radians. An estimate of the equivalent percent infestation rate can be made using the following formula:

$$\text{Percent infestation} = 100\ [\text{Sine (radians)}^2]$$

Impact.--A method similar to Stoszek's (1973) and Stoszek et al. (1981) was used to calculate height growth reduction due to shoot borer. Twelve of the total population of plantations were used for impact assessment. These were equally divided between the following average percent infestation rate classes: 5-10 percent, 15-20 percent, and 25-30+ percent. Each ponderosa pine internode length (1979-1981) was grouped into one of four infestation categories:

UU - Uninfested internode originating from a previously uninfested internode.

UI - Uninfested internode originating from a previously infested internode.

IU - Infested internode originating from a previously uninfested internode.

II - Infested internode originating from a previously infested internode.

Only trees in which the longest internode was in the UU infestation category were used for further analysis under the assumption that the uninfested internodes expressed a tree's "true" potential growth rate. Each of the infested internodes was compared with the uninfested internode from the same tree to calculate a growth rate reduction due to shoot borer infestation. Percent growth reduction for an internode was calculated using the following equation:

$$1 - \frac{\text{length of infested shoot}}{\text{length of uninfested shoot}} \times 100 = \text{percent height growth reduction}$$

An average height growth reduction was calculated for each of the infested categories (IU, UI, II). The percentage of each infestation category found in each infestation rate class was calculated. From this information the total shoot borer caused height growth reduction for a plantation was estimated.

RESULTS

Strata Means.--Strata means and 95 percent confidence intervals are presented for each of the sample strata: geographic region (table 1), elevational zone (table 2), vegetation series (table 3). In addition, the same information is presented for each of the six National Forest samples (table 4).

From table 1 it can be seen that west-central Montana has a significantly lower shoot borer infestation rate than the other two geographical regions. Elevational zone also contributes significantly to differences in infestation rates (table 2). Plantations at low elevations generally have higher infestation rates than those at high elevations.

Table 1.--Mean shoot borer infestation rate (percent) and 95 percent confidence intervals for each geographical region.

West-central Montana--Bitterroot NF & Lolo NF
7.14 percent $\pm$ 2.45 n = 49

Northwestern Montana--Kootenai NF & Flathead NF
12.83 percent $\pm$ 3.02 n = 23

Northern Idaho--Panhandle NF & Clearwater NF
11.72 percent $\pm$ 4.81 n = 8

Table 2.--Mean shoot borer infestation rate (percent) and 95 percent confidence intervals for each elevational zone.

3,000-4,500 ft.
12.47 percent $\pm$ 2.59 n = 41

4,600-5,500 ft.
7.60 percent $\pm$ 3.14 n = 24

5,600-7,000 ft.
3.00 percent $\pm$ 2.84 n = 15

Table 3 shows a significant difference between infestation rates in various vegetation series; Douglas-fir and subalpine fir series showing the lowest infestation rates and the grand fir series exhibiting the highest rates. The differences seen between infestation rates in each Forest (table 4) can largely be attributed to the Forest's mean elevation. The Kootenai National Forest, having the highest infestation rate, is primarily in the lowest elevational zone where high infestation rates are expected (table 2). In contrast, the Bitterroot National Forest, which is at a substantially higher elevation, has the lowest infestation rate.

Table 3.--Mean shoot borer infestation rate (percent) and 95 percent confidence intervals for each vegetation series.

Douglas-fir series
7.84 percent ± 2.45 n = 52

Grand fir series
12.55 percent ± 2.60 n = 24

Subalpine fir series
7.50 percent ± 9.85 n = 4

Table 4.--Mean shoot borer infestation rate (percent) and 95 percent confidence intervals for each National Forest.

Lolo National Forest
8.04 percent ± 4.03 n = 21

Bitterroot National Forest
6.47 percent ± 3.09 n = 28

Flathead National Forest
7.64 percent ± 2.69 n = 9

Kootenai National Forest
16.16 percent ± 3.75 n = 14

Clearwater National Forest
14.25 percent ± 6.83 n = 5

Idaho Panhandle National Forest
7.50 percent ± 2.46 n = 3

Table 5 presents descriptive statistics for each of the plantations sampled.

Table 5.--Descriptive plantation statistics.

Stand	Elevation	Age	Avg. height	Ponderosa TPA 1/	Total TPA	Ponderosa BA 2/	Total BA	Percent infestation
Lolo National Forest								
30103002	4100	18	11.97	270	280	17.1	17.2	18.75
30103004	4100	14	6.96	60	200	0.5	1.5	0.00
30403004	5800	16	8.19	240	330	6.4	7.9	1.25
31909001	5000	17	10.31	210	240	7.4	7.7	3.75
32705003	4400	18	7.00	120	140	1.2	1.4	0.00
34606019	5200	16	7.9	180	210	1.9	3.9	0.00
37402018	5400	12	6.03	160	160	0.6	0.6	0.00
50401015	4100	14	7.89	290	350	4.2	5.0	10.00
51503002	4700	16	9.19	170	170	5.0	5.0	7.50
51503010	4600	16	11.99	200	350	12.2	13.9	18.75
51701003	4900	16	9.63	100	100	3.8	3.8	1.25
51705013	4700	17	14.27	210	210	15.8	15.8	12.50
52802004	3800	17	10.39	170	270	5.7	8.3	8.75
52802016	4600	17	8.12	90	120	1.3	1.6	0.00
53003011	4200	18	8.72	170	180	5.7	5.7	12.50
62902002	5200	15	8.50	150	160	4.4	4.4	2.50
70102022	3400	18	13.91	210	320	15.9	21.3	36.25
71602004	3400	18	16.46	180	210	24.5	26.5	13.75
73501001	4400	18	12.39	140	150	11.0	11.8	18.75
76401020	4400	17	8.39	60	60	1.1	1.1	0.00
76501006	4600	15	10.69	100	250	4.2	5.0	2.50
Bitterroot National Forest								
10204001	6000	15	8.05	160	160	2.5	2.5	0.00
10802001	5000	16	10.49	210	230	6.5	6.6	0.00
10801002	6000	14	8.84	210	270	3.1	4.0	0.00
11505002	6000	15	7.73	170	170	3.0	3.0	0.00
24501005	6000	15	8.89	110	250	2.1	4.0	0.00
24501008	6500	15	8.57	130	140	3.4	3.4	0.00
25202005	6000	14	9.31	90	90	3.3	3.3	0.00
26403005	5500	18	10.66	170	200	5.9	6.6	20.00
26406002	6100	18	11.63	230	240	12.9	14.3	5.00
26502008	6000	12	8.47	140	140	3.8	3.8	3.75
26505004	4500	16	11.19	140	140	5.6	5.6	26.25
26505006	5500	16	19.83	160	160	6.1	6.1	18.75
28703002	5000	14	19.72	80	140	5.2	5.5	18.75
28703003	5400	14	10.10	150	220	3.8	4.7	7.50
28705004	5000	14	11.00	180	190	5.7	5.7	20.00
30202001	5800	15	10.65	130	130	3.9	3.9	11.25
30701001	5200	16	9.81	160	180	4.9	5.6	0.00
31801006	6000	15	8.48	150	170	4.0	4.2	1.25
32102001	5500	16	12.19	160	170	10.0	10.0	5.00
39301003	6000	15	7.21	50	70	0.5	0.7	0.00
39209001	5500	13	7.75	80	90	1.1	1.3	0.00
42405001	4000	12	7.76	320	320	4.4	4.4	8.75

Table 5.--continued

Stand	Elevation	Age	Avg. height	Ponderosa TPA 1/	Total TPA	Ponderosa BA 2/	Total BA	Percent infestation
Flathead National Forest								
12201001	3400	14	10.50	130	180	6.8	7.9	10.00
20301014	3500	16	13.08	160	250	10.8	13.9	12.50
20301015	3600	15	11.15	60	60	2.7	2.7	5.00
20601002	3800	15	15.77	250	280	25.4	25.6	10.00
20901009	4000	15	11.86	90	90	4.7	4.7	6.25
20901004	3600	16	14.78	60	130	3.5	7.1	13.75
21101001	3800	16	13.43	140	170	8.8	10.6	2.50
21301006	3600	14	10.11	140	150	4.2	4.9	6.24
21301021	4300	16	11.21	70	180	2.6	4.1	2.50
Kootenai National Forest								
40101001	2900	16	23.99	90	90	21.4	21.4	8.75
40301001	2700	13	11.71	90	90	4.8	4.8	23.75
40502002	2400	12	11.86	100	100	7.8	7.8	11.25
40703002	3000	18	13.94	160	380	12.4	13.8	22.25
41401004	2400	13	11.37	100	180	9.1	11.8	10.00
51301001	4100	15	16.05	100	210	11.8	14.8	17.50
51602001	3500	14	11.88	110	190	7.1	11.0	30.00
53902004	4600	14	8.80	180	280	6.6	7.2	13.75
60201001	4700	17	14.10	110	130	8.9	10.3	17.50
62502005	4100	14	6.87	30	60	0.4	0.4	2.50
70406005	2700	15	12.61	70	140	2.4	4.2	21.25
72401004	3500	15	12.49	180	250	17.4	19.4	20.00
Clearwater National Forest								
28303004	3100	14	12.52	90	90	7.5	7.5	12.50
27304001	3200	18	21.65	170	230	25.7	27.3	10.00
25204001	2800	14	16.61	210	220	25.5	25.7	25.00
25202006	3300	15	17.49	80	120	9.6	9.6	5.00
25202005	3200	15	15.69	120	120	14.3	14.3	18.75
Idaho Panhandle National Forests								
72006044	3400	15	12.06	30	160	1.5	2.4	8.75
64001005	2500	17	14.38	160	230	14.7	16.5	8.75
64001003	3200	17	11.78	100	100	7.9	7.9	5.00

1/ Trees per acre
2/ Basal area

Single Variable Regression Models.--The relationships between all single site and stand variables and the incidence of shoot borer infestations are presented in table 6. The average diameter of the ponderosa pine on a plantation appears to be, by far, the best single predictor of shoot borer infestation rate (R^2 = .361). Other important variables are annual basal area growth rate (BA/AGE), (R^2 = .342), basal area (R^2 = .327), average annual height growth over the last 3 years (R^2 = .320) and elevation of the plantation in 100's of feet (R^2 = .319).

Table 6.--Linear regressions of single site and stand variables on infestation rate.

Variable	Equation	1-2	SSE
Site			
Elevation	0.605 - 0.0082X	.319*	.135
Plantation age	0.095 + 0.0095X	.010	.163
Slope	0.327 - 0.0031X	.103*	.155
Ponderosa pine stocking			
Trees/acre	0.177 + 0.0004X	.206	.162
Basal area	0.137 + 0.0143X	.293*	.138
% Trees/acre	0.322 - 0.010X	.016	.163
% Basal area	0.190 + 0.0006X	.003	.164
Average d.b.h.	- 0.004 + 0.0899X	.361*	.131
Other species stocking			
Trees/acre	0.216 + 0.0007X	.039	.161
Basal area	0.201 + 0.0471X	.118*	.154
Average d.b.h.	0.208 + 0.0289X	.040	.161
All species stocking			
Trees/acre	0.135 + 0.0006X	.067	.158
Basal area	0.125 + 0.0142X	.327*	.134
Average d.b.h.	0.023 + 0.0878X	.295*	.138
Ponderosa pine growth rate			
Height/age	- 0.081 + 0.4432X	.316*	.136
1981 Height	- 0.067 + 0.0279X	.319*	.135
Height growth	- 0.121 + 0.3034X	.320*	.135
BA growth/age	0.131 + 0.2325X	.306*	.136
BA growth/TPA/age	0.129 + 0.0034X	.283*	.139
All species growth rate			
Basal area/age	0.119 + 0.2314X	.342*	.133
Basal area/TPA/age	0.140 + 0.0034X	.238*	.143

SSE - Standard Error of Estimate.
* - Significant at 95 percent level.

Multivariable Regression Model.--The multiple variable relationships tested lead to the development of a model which accounted for 60 percent of the variation in shoot borer infestation rate. The model is expressed by the following equation:

$$Y = 0.6891 + 0.0007X - 0.0147X_2 - 96.3503X_3 + 3.3015X_2X_3$$

where:

Y = a plantation's average shoot borer infestation rate (in radians)

X_1 = number of ponderosa pine/acre

X_2 = plantation elevation (100's of feet)

X_3 = annual ponderosa pine basal area growth increment PPBA/PPTPA/AGE

X_2X_3 = interaction term ($X2*X3$)

R^2 = .602 SEE = .106 Infestation rate mean = .2415

Impact.--Table 7 presents the estimated percent height growth reduction for a plantation at three shoot borer infestation rate classes. Growth reductions range from 5.00 percent at an infestation rate of 5-10 percent to 16.28 percent at an infestation rate of 25-30 percent.

Table 7.--Height growth loss by infestation rate class and category.

Internode infestation	Percent growth	Percent of internodes in infestation category at infestation rate of			Percent growth loss at infestation rate of		
		5-10%	15-20%	25-30%	5-10%	15-20%	25-30%
UU	0	84.17	65.83	48.74	0	0	0
UI	38.85	7.50	14.17	21.67	2.91	5.51	8.42
IU	24.09	7.50	14.17	21.67	1.81	3.41	5.22
II	33.33	0.83	5.83	7.92	0.28	1.94	2.64
Percent height growth reduction					5.00	10.86	16.28

APPLICATION OF THE MODEL

A ponderosa pine plantation's risk to shoot borer can easily be calculated utilizing the model developed in this report. All of the data necessary for inclusion in the model are readily available or can be easily obtained. An example follows using data from Lolo National Forest stand number 301003002.

X_1 = ponderosa TPA = 270

X_2 = elevation = 41 (100's of ft)

X_3 = ponderosa BA/TPA/AGE = 17.1/270/18 = .0035

X_2X_3 = .0035 x 41 = .1443

$$y = 0.6891 + 0.0007X_1 - 0.0147X_2 - 96.3503X_3 + 3.3015X_2X_3$$

y = .0.4146 infestation rate in radians

To convert "infestation rate in radians" to "infestation rate percent" utilize the formula:

$$100 \left[\text{sine (radians)}^2\right]$$

In this example:

0.4146 is infestation rate in radians;

Convert to degrees (57.2958^{o}/radian):

(0.4146) (57.2958) = 23.755^{o};

sine of 23.755^{o} = 0.4028

$(0.4028)^2$ = 0.1623 x 100 = 16.23% Infestation rate percent

The calculated infestation rate (16.23 percent) is close to the actual infestation rate for this particular plantation (18.75 percent). This procedure may be used to acquire an estimated infestation rate for any ponderosa pine plantation for which the proper data have been collected.

Shoot borer caused impact at this infestation rate can be estimated by using table 7. The infestation rate of 13.45 percent is closest to the 15-20 percent infestation rate class which has a percent height growth reduction of 10.86 percent. Estimates of volume reduction may be made using local managed yield tables and the estimated height growth reduction for the plantation. Stoszek et al. (1981) established that shoot borer infestation rates remain fairly constant throughout a rotation beginning at year 10. Volume yields at rotation can be made with and without shoot borer height growth reduction to esimtate volume reduction. Estimates of volume reduction will be conservative since yield tables are derived from stands having some shoot borer activity.

DISCUSSION

This survey has produced a tool for the evaluation of shoot borer impact. The model developed for shoot borer infestation rate prediction is based on readily obtainable management information: elevation, stocking, and basal area growth increment. The model will be helpful to the manager in determining where shoot borer infestations may become a problem. These variables are not of a nature that allows for silvicultural manipulation. However, when linked with impact (growth reduction) projections, the hazard-predictive model can be used to reassess plantation yield projections utilizing local yield tables. From this, costs and benefits of alternative plantation management practices can be assessed. Once the manager has an idea of what values are being lost, he will then be able to determine what control measures (if any) are warranted.

It is possible that on sites of high risk and high impact, application of mating disruptive synthetic sex attractants may be cost effective for reducing the infestation rate to acceptable levels (Sartwell et al. 1980b). Thinning a plantation to reduce the stocking of ponderosa pine would reduce the incidence of shoot borer but would also tend to be counter-productive. During the plantation establishment phase, nonhost species might be planted provided they are found to have higher growth potential than the shoot borer impacted ponderosa pine.

Applicability of the model and impact estimates are limited to the strata from which the data were collected. This includes ponderosa pine plantations in western Montana and northern Idaho between the ages of 12 and 18 years, and 3,000-7,000 ft in elevation. Attempts to extrapolate this information to areas outside these strata may cause significant errors.

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